The Digital Photographic Measurement Method: A Reliable Clinical Measurement Technique of the Hindfoot?

Thesis

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By

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Abstract

Current clinical methods to evaluate hindfoot alignment have poor to moderate reliability among clinicians. The digital photographic measurement method may offer a clinically useful and reliable evaluation technique, but research is limited. The purpose of this study was to investigate the reliability of the digital photograph measure of hindfoot alignment among novice examiners. The study included males and females between the ages of 18-25 who did not have a history of previous foot injury, have a general medical condition affecting the foot, or prior foot surgery. For the testing anatomical landmarks were marked with a felt-tipped skin marker and each participant was positioned in a standard weight-bearing position. Digital photographs were taken from the posterior view of each foot for each participant. Prior to the measurement phase of the study, novice examiners participated in standardized instruction session regarding goniometric measurements of hindfoot alignment. At the measurement session, each novice examiner provided 3 measures of hindfoot alignment from each photograph, which were blinded and presented to each examiner in a randomized order. The measurement testing session was completed twice with each examiner with a week between the sessions to test the reliability of the measurement technique. For the analysis, descriptive information including inter- and intra-observer reliability was calculated using SPSS 19. The first measurement session resulted in an intra-class correlation of 0.291. The second measurement session resulted in an intra-class correlation of 0.341. Between the two testing session, individual examiner measurements resulted in correlations from 0.556 to 0.809. This study found that there was not high reliability among novice examiners when

using the digital photographic measurement method to evaluate hindfoot alignment. However, the study did show that there is higher reliability within individual examiners when results are compared over two separate measurement sessions. This indicates that if an examiner uses the same measurement technique each session, they will have reliable and repeatable measures.

Dedication

This document is dedicated to my family, friends, and all the advisors and professors who helped me through the research process.

Acknowledgements

I would like to acknowledge all the individuals who have helped me through this process. My advisor Laura Schmitt, who taught me everything that I now know about the world of research. She helped me to realize that research was my passion. Ashley Cole, who pushed me to start a research thesis and was there to support me the entire way through. I would also like to acknowledge my classmates who participated in my research. This research could not have been accomplished without their continued dedication to the project.

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CHAPTER 1

Introduction

The hindfoot is comprised of the calcaneous, the talus and anteriorly the cuboid. Both distally and laterally the calcaneous takes on an inclined position articulating with the talus to for the subtalar joint (Menz, 1995). Research studies in the past have focused on the frontal-plane component of the general foot stance when measuring hindfoot alignment (Vinicombe, 2001). Current measurement techniques of the hindfoot (the relationship between the calcaneous and distal lower limb) show poor to moderate reliability, especially among novice clinicians (Vinicombe, 2001).

In order to better assess the hindfoot in the clinic, an accurate and clinically useful measurement method is necessary. The Digital Photographic Measurement Method (DPMM) has been shown to be a reliable measure of alignment in other parts of the foot and may be a useful method to evaluate hindfoot alignment (Mall, 2007). The DPMM to evaluate hindfoot alignment may allow for improved repeatability and reliability among clinicians. An effective and reliable technique to measure hindfoot alignment may allow clinicians to categorize hindfoot problems in a consistent way that will guide treatment and promote evidence-based practice.

Statement of Purpose

The purpose of this study is to determine whether the DPMM is a reliable measurement technique to evaluate hindfoot alignment by novice examiners. Specifically, this study will determine the inter- and intra-rater reliability of the DPMM among novice examiners, when the measurement technique is applied to evaluation of varus and valgus hindfoot alignment.

Research Hypothesis

1. It was hypothesized that the DPMM will provide high inter-rater reliability among novice examiners.
2. It was hypothesized that the DPMM will provide high intra-rater reliability between testing sessions among novice examiners.

Null Hypothesis

1. The DPMM will not provide a high inter-rater reliability among novice examiners.
2. The DPMM will not provide high intra-rater reliability between testing session among novice examiners.

Objectives

1. To provide evidence based research on the DPMM as a measure of hindfoot alignment.
2. To provide both inter- and intra-rater reliability data on the DPMM among novice examiners.
3. To provide specific instructions to novice examiners on how the DPMM should be performed.

Assumptions

1. Investigator had experience in finding subtalar neutral in a weight-bearing position
2. Investigator could reliably take a digital photograph
3. Novice examiners had a working definition of valgus and varus angles
4. Novice examiners understood how to measure the angle between the distal lower extremity and calcaneous

CHAPTER 2

Abnormal hindfoot motion and position have been associated with numerous pathologies, including metatarsal stress fractures, shin splints, and plantar fasciitis (Vinicombe, 2001), which affect both athletes and the lay population alike. Clinical decision-making regarding treatment interventions are guided by evaluation of foot structure and alignment, including alignment of the hindfoot. In order to ensure that the measurements being made of hindfoot alignment are accurate, clinicians should seek the use of evaluation techniques that are both reliable and valid. Comprehensive evaluation of the hindfoot relies on static and dynamic measures of alignment; this is the reason most podiatric diagnosis involves both static measures of foot posture and dynamic measures of foot posture during gait or weight bearing activity. (Vinicombe, 2001)

Anatomy

Subtalar Joint

The hindfoot is comprised of the calcaneous, the talus, and anteriorly the cuboid. Both distally and laterally the calcaneous takes on an inclined position articulating with the talus to form the subtalar joint. The joint between the calcaneous and cuboid is considered the calcaneo-cuboid joint. Because large inconsistencies exist in the structure of the cuboidal shaped calcaneous, significant variations in structure exist in population. (Menz, 1995)

Biomechanics

The modern definition of neutral structure in the foot states that bipedal stance, the person's body weight should be evenly distributed between the two feet (Kirby, 2000). In quiet standing, the gastrocnemius muscle is activated primarily to allow the foot to become slightly plantar flexed consequently allowing the line of action of the center of mass to fall just anterior to the ankle joint axis (Kirby, 2000). To then maintain a center of mass within the balance area between the feet, extrinsic muscles will contract at various moments (Kirby, 2000). Normal gait mechanics may not necessarily be associated with a foot that exhibits what is traditionally considered a neutral subtalar joint position during full weight-bearing bipedal stance (Kirby, 2000). Individuals with a neutral subtalar position have been noted exhibiting symptoms that are associated with malalignments of the foot (Kirby, 2000). To obtain the most mechanically functional position for the foot, a balance between supination and pronation must be achieved across the subtalar joint axis during standing weight-bearing bipedal stance (Kirby, 2000).

Current Methods to Evaluate Food Structure

Subtalar Neutral Position

During both weight bearing and non-weight bearing the subtalar joint is considered one of the most complex joint in the human body. For decades the definition of subtalar joint neutral was associated with the idea of it being the position in which the longitudinal midlines of the leg and heel were parallel (AAOS, 1965). Recently the idea of the subtalar joint reaching a relative zero position has been considered the subtalar neutral position. In order to meet this aforementioned zero position the patient must be in a prone position with the forefoot passively pronated and the ankle dorsiflexed until a soft end-feel is encountered and consequently in that position the head of the talus cannot be palpated or is felt to extend equally at the medial and lateral borders of the talonavicular joint (Elveru et al, 1988). In more simple terms the subtalar neutral position can be described as the point in which the concave and convex surfaces of the talus are completely congruous (Yan-xi, 2008). (Elveru et al, 1988; Menz, 1995; Yan-xi, 2008)

It is customary to measure hindfoot alignment with the foot in subtalar joint neutral position. The most clinically useful and often used way to ensure that the foot is in the subtalar neutral position is to palpate just anterior to the lateral malleolus and just inferior and anterior to the medial malleolus, respectfully, in those areas the lateral and medial aspects of the talus become palpable (Giallonardo, 1988). In a majority of instances the patient is positioned laying prone on the table while the forefoot is used to drive the talus toward the skin for palpation. (Giallonardo, 1988)

Navicular Drop Measurement Method

The navicular drop test is thought to be useful as a measurement of foot mobility, specifically related to the amount of pronation a foot exhibits. The test has been described as the process in which the subject is seated with knees at ninety degrees and both feet flat on the ground. The subject is then instructed to stand flat on both feet, while the clinician located the neutral position of the foot. Once the neutral position has been located the subject is then instructed to stand on one leg. This measurement is taken during the one legged stance due to research showing measurements taken from this position more accurately represent the position of the foot during the midstance phase of gait (Vinicombe, 2001). Once the one legged stance is accomplished a white note card is placed at a right angle to the foot to which the navicular high is marked. Next the person is asked to relax on both feet and go back into the one-footed stance. The same make is made on the note card. The difference between this neutral and relaxed navicular position is what is known as the navicular drop. (Vinicombe, 2001)

Although many studies have been attempted to recreate the navicular drop scenario and attempt to validate the test, a major problem with tester inexperienced has been discovered. When the test is recreated multiple times, with testers who are not specifically trained in the exact manner on the navicular drop measurement poor inter-rater reliability occurs (McPoil, 2008). This may be because of the contributing factor of having to consistently place the subtalar joint in its neutral position using palpation (McPoil, 2008).

Navicular Drift Measurement Method

The navicular drift measurement is otherwise known as a projection onto the transverse plane of the navicular displacement that occurs with an alteration in the hindfoot position (Vinicombe, 2001). Neutral and relaxed stance are found in the same manner as was in the navicular drop test, but a white sheet of paper was placed under the subject’s foot during the measurement. The position of the navicular, as indicated by the bottom corner of the business card was marked on the paper (Vinicombe, 2001). The actual navicular drift measurement is recorded as the difference between the marked location of the navicular in the neutral stance and the resting/relaxed position (Vinicombe, 2001). It has been concluded that both measurements are only moderately reliable and thus of somewhat limited value in the clinical evaluation of foot posture (Vinicombe, 2001).

Arch Height Measurement Method

In order to assess malalignments associated with the hindfoot, measurements of the lateral aspect of the foot may play an important role. The distance from the highest point of the soft-tissue margin of the medial longitudinal arch to the ground below is considered the arch height measurement (Weinger-Ogilvie, 1998). But, this method is controversial in the intertester and intratester reliability due varying grades of reliability discovered in recent research (Weinger-Oglivie, 1998).

With the subject in a relaxed neutral position the top of the arch is marked for visual reference. A caliper is the measurement device used to take specific measurement from the ground to the top of the arch region marked prior. When this measurement technique is repeated research has confirmed significant differences between two observers, low intertester reliability, but no significant differences between two visits for the same observer, moderate intratester reliability (Weinger-Ogilvie, 1998). (Weinger-Ogilvie, 1998)

Mirrored Photo Box and Digital Photography Measurement Method (DPMM)

To assess the foot using any photographic method four specific spots on the foot have, in the past, been used as markered landmarks, the navicular, calcaneous, and both the base and head of the first metatarsal. Using a caliper, foot length, truncated foot length, navicular height, height of the dorsum at 50% of foot length, and the first metatarsal angle were measured prior to obtaining the digital photographs (Mall, 2007). The caliper measurements are used to compare and validate the photograph measurements. The foot is consequently placed in a mirrored photo box, where the subject is instructed to stand at 90% of full weight bearing, and digital photographs are taken of each foot, in order to ensure bilateral comparison. For best results measurements using photographic techniques should be done twice, within one week of each other. (Mall, 2007)

Results from photo box digital photography showed that when compared to caliper collection methods, the photo box photographs cut collection time down dramatically. The photo box photographs demonstrate having a slightly better reliability and validity when compared to similar caliper measurements as boney landmarks and percentage of weight bearing stays the same throughout each measurement (Mall, 2007). Photo box photographs have been proven as an acceptable option for the characterization of foot type (Mall, 2007).

Inconsistencies in Current Hindfoot Measurement Techniques

For any hindfoot and/or subtalar neutral to be potentially useful among clinicians, it must have some form of validity, which has been defined as the extent to which a test or set of operations measures what is supposed to measure (Elveru, 1988). In order to better categorize an abnormally positioned foot, a reliable and valid measurement technique must be used (Weiner-Ogilvie, 1998). But, as current and past research has shown methods of foot position measurements can be inherently difficult because of the complex interactions of the joints of the foot (Weiner-Ogilvie, 1998). Research studies in the past have greatly focused on the frontal-plane component of the general foot stance. Many times the general foot posture is categorized using the relaxed calcaneal stance position. The problem with this generalized method is that inexperienced observers were seen to have struggled with the technique leading to low interobserver reliability ratings. (Weiner-Ogilvie, 1998)

The intra-tester reliability of goniometry measurements of the subtalar joint in the neutral position is only moderate when measurements are taken over a short period of time (Menz, 1995). Subtalar joint neutral location of a non-weight bearing subject using both range of motion calculations and talar congruency techniques is poor (Menz, 1995). Having an examiner who has a greater level of expertise in the area of subtalar joint measurements only improves the reliability of the measurements taken by a marginal number. (Menz, 1995)

Research studies in the past have focused greatly on the frontal-plane component of the general foot stance when measuring hindfoot alignment (Vinicombe, 2001). These measurement techniques of the hindfoot show poor to moderate reliability, especially among novice clinicians (Vinicombe, 2001). This suggests that further investigation must be done on techniques of hindfoot measurement, including the DPMM. Therefore, the purpose of this study is to determine whether the DPMM is a reliable measurement technique to evaluate hindfoot alignment by novice examiners.

CHAPTER 3

Subjects

Males and females between the ages of 18-25 were recruited from the student population at The Ohio State University. Nineteen subjects were recruited through flyers placed around campus, emails sent to the student athletic training program, and through personal contact in athletic training classes and the Ohio State Biomechanics Lab.

Participants were included if they between the ages of 18-25 years old, and were physically active. Physically active was defined as any exercise or athletic participation meeting a minimum of 60 minutes per week. The participants were excluded if they had a general medical condition that affects the feet, such as diabetes, have had a foot and/or lower limb fracture, stress fracture, significant strain/strain, or have had foot and/or lower limb surgery. Participants were randomly assigned an identification number to allow the novice examiners to remain blinded during the measurement period.

Study Design

This study utilizes a single session study and is an experimental study design. The study is designed as a blind control group. In the study the novice measurers will be blinded each of the participants.

Instruments

Digital Goniometry

Digital goniometry measurements are defined as the measurement of range of motion within a joint. The digital goniometry served as a measurement of the angle that is between the distal lower extremity and the calcaneous in the frontal plane. This measurement is defined as hindfoot alignment. For the digital goniometer method, the same coded and blinded digital photographs were displayed on a computer screen and a computer software program (Image J 1.44, National Institutes of Health) was used to measure the angle using a digital goniometer. See figure 1.

Procedures

Screening

The participants were brought to St. Johns athletic training room 5 minutes prior to the photography session in order to be screened for inclusion. Those participants that fit the inclusion criteria, and had read and signed both the HIPPA and consent forms associated with the study were asked to further participate.

Marking

Participants asked to further participate in the study following the screening period began the marking period. Participants were asked to remove shoes and socks and ensure that all of the distal lower extremity, ankle, and foot were visible. Participants were instructed to stand double-leg weight-bearing. With the investigator positioned directly behind the subject subtalar neutral was identified. In order to find subtalar neutral the examiner placed the left thumb and index fingers on the anterior aspect of the foot over the sides of the talar dome. Using the right hand, the examiner would grasp the foot from the lateral side and invert and evert the foot and ankle until the neutral position of the foot is determined. The talus is in its neutral position when it is aligned symmetrically between the thumb and index finger. Once that position had been verified as subtalar neutral by the investigator, two marks were made on the foot. These marks were made with a felt-tipped pen and were a small horizontal line approximately a half-inch in length. One mark was made at the most superior aspect of the posterior calcaneous. A second mark was made 6 cm above the mark on the superior aspect of the posterior calcaneous. This process was repeated on both the left and right foot.

Photograph

Each participant was then instructed to relax and step on two scales that were places one next to the other. In a double-legged weight-bearing position the participant was instructed to stand with feet shoulder width apart in line with the vertical line placed on each of the scales. Once the vertical line was identified the participant was cued to place the lateral aspect of the 5^{th} metatarsal on the vertical line. This was done for both the left and right foot. Once horizontal line was marked on each of the scales where the most prominent portion of both the left and right calcaneous would line up. Once a comfortable double-legged weight-bearing position was found, the participant was instructed to continue to place equal weight over both the left and the right foot. To standardize this, each scale was to read the same weight within 2-3 pounds.

The investigator placed the digital camera 52 cm from the two scales in which the subject was standing upon. The digital camera sat on a box that was 30.5 cm in height. The box that the camera sat upon was 56 cm long. When the photograph of the left foot was taken the digital camera sat 15.5 cm in from the right left edge of the box. When the photograph of the right foot was taken the digital camera sat 6.5 cm in from the right edge of the box. The digital camera was positioned vertically to ensure that the distal lower extremity ankle and posterior calcaneous were visible. At this point four vertical photographs were taken of the both the participant's right and left foot. The first photograph of the right and left foot contained the participant's unique identification number. Photograph set up is presented in figure 2, 3, and 4. The first photograph of both the right and left foot were used for the measurement testing session. Photograph examples are presented in figure 5 and 6.

Photograph Blinding

In order to blind the five novice examiners from the subject's identity each chosen photograph was given, at random, a letter and number that would be used during each of the measurement session. Two separate sets of letters and numbers were used during the two separate measurement sessions. At random, each of the nineteen subjects were either chosen as a right foot or a left foot participant. This meant that during the measurement sessions the one photograph of each subject was selected, this being either a right or left foot photograph. This same right or left foot photograph was used during the second session as well as the first.

Digital Goniometry Measurements

Five novice examiners were recruited from The Ohio State University athletic training program. These five novice examiners were in their third year of the program and all had completed the same curriculum regarding the foot. One at a time each novice examiner reported to The Ohio State University Biomechanics Lab. Once the novice examiner was present they were given specific instruction regarding the Image J software program to measure hindfoot angle. Originally six novice examiners were selected to participate in the study. The first novice examiner reported for the first measurement session and after being given specific instruction as to how to use the program, still had questions regarding recognition of a valgus and varus angle during the measurement session. This prompted a change in the instruction period prior to the second novice measurer completing the first measurement session. Due to the change in instruction, the first novice examiner's results were not included in the analysis.

To use the program each examiner was instructed that they would be read a participant letter/number. This would correspond with a letter/number on their measurement sheet where the angle was to be recorded. At this point the examiner would use the "angle tool" to draw an angle on the photograph that would correspond with the hindfoot angle of the foot. To draw the angle the curser must be clicked once, this will begin a yellow line, to stop that yellow line the curser will be clicked once more. From that point a second yellow line will begin, which will be ended with one more curser click. The angle that the two lines form will be known as the hindfoot angle. This is the angle that is to be recorded on the data sheet.

To measure this angle the novice examiner clicked the analyze button on the tool bar of the program. From there the novice examiner drug down to the measure option under the analyze button. The examiner then read/recorded the angle that was listed in the pop-up window. Once that angle was recorded the novice examiner was asked to choose whether the angle was valgus or varus. Example digital goniometer angle presented in figure 6.

A valgus angle was defined as an angle in which the calcaneous is everted relative to the long axis of the tibia. A varus angle was defined as an angle in which the calcaneous is inverted relative to the long axis of the tibia. During the measurement period the novice examiner had the ability to read these definition and look at drawing representations of valgus and varus hindfoot angles. Valgus and varus angle drawing representations presented in figure 7.

This measurement session was completed once more, a week after the first measurement session, in the same fashion. In order to randomize and blind the novice examiner each photograph was given a different letter/number from the first measurement session.

Statistical Analyses

Statistical analysis was done with IBM SPSS Statistical software (version 19.0, SPSS Inc, Chicago, IL). Descriptive information and inter-rater and intra-rater reliability were calculated. Inter-rater reliability is defined as the extent of agreement between two or more clinicians independently. A high rate of agreement is understood as a high inter-observer reliability. Intra-rater reliability is defined as the amount of agreement that results when the same clinician measures the same subject on two or more separate occasions. Just as with the inter-observer reliability the higher the rate of agreement between measurements, the higher the intra-observer reliability.

To analyze inter-rater reliability among novice measurers the Intraclass Correlation Coeffiecient (ICC 2,1) was used and Pearson Correlation Coefficient were used to analyze the intra-rater reliability among novice examiners between testing sessions.

CHAPTER 4

Descriptive Statistics

A total of nineteen participants were recruited for this study. Four males and fifteen females participated in the study. The average age of the participant was 20.8 years. Three subjects participated in physical activity one time per week. Five participants participated in physical activity two times per week. Four participants participated in physical activity three times per week. Three participants participated in physical activity four times per week. Three participants participated in physical activity five times per week. One subject participated in physical activity 6 times per week. Two of the subjects currently and/or have previously worn orthotics. Nine participants have had what they would classify as minor ankle sprains, where they were able to return to activities of daily living within one week of the injury. Descriptive statistics are presented in table 1.

Digital Goniometry Measurements

During the first measurement session it was shown that the intra-class correlation was 0.291 for single measures. The 95% confidence interval lower bound was 0.102 and upper bound was 0.546. Intra-class correlation presented in table 2.

During the second measurement session it was shown that the intra-class correlation was 0.341 for single measures. The 95% confidence interval lower bound was 0.145 and upper bound was 0.592. Intra-class correlation presented in table 2.

Individual examiner correlations were calculated, when comparing individual examiner results from the first measurement session to the second measurement session. Examiner one had a Pearson correlation of 0.754. Examiner two had a Pearson correlation of 0.628. Examiner three had a Pearson correlation of 0.556. Examiner four had a Pearson correlation of 0.712. Examiner five had a Pearson correlation of 0.809. Examiner correlations presented in table 3.

CHAPTER 5

The purpose of this study was to determine whether the DPMM would provide a reliable measurement technique for hindfoot alignment. Specifically, this study determined the inter-rater and intra-rater reliability of the DPMM, when measurement technique was being completed on the hindfoot by novice examiners. Our results indicate that across examiners the DPMM has low reliability. But, when one examiner completes the same measurement technique one two separate occasions, it is shown to be reliable within the examiner.

Digital Goniometry Measurements

It was shown that the reliability within five separate novice examiners was well below acceptable. Reliability among examiners did improve during the second measurement session from ICC 0.291 at the first session to ICC 0.341 at the second session. It was hypothesized that the reliability among examiners would be high, if training level was equal, anatomical marks were made appropriately, and digital photographs pictured the distal lower extremity and calcaneous. Although these variables seem to be present, the reliability was not as high as hypothesized.

The associated of the measures of individual examiners between testing sessions ranged from being moderately reliable to highly reliable although there was a large variance between examiners as to how reliable results were. It was hypothesized that the agreement of measures within an individual examiner would be high and statistically significant. Aside from examiner three, the associated of measures between testing session for the four other examiners was moderate-high and statistically significant.

Differences among examiners may be accounted for with differences in prior knowledge or understanding of hindfoot alignment.

Limitations

Limitations include the fact that the novice examiners were six athletic training students in their third and final year of an accredited undergraduate program. Although all of these students received the same education, and were taught from the same textbooks, it cannot be ensured that all six of the novice examiners understood hindfoot valgus and varus in the same way. All six of the novice examiners were given the same pre-measurement training in order to combat this issue. But, this may have negatively affected the study since each novice examiner had a different idea as to how to properly measure the hindfoot angle. A second limitation included the fact that in certain instances the novice examiners would disregard the fact that there was a mixture between both right and left feet. It was noted that when the digital photographs switched from a right foot to a left foot the examiner would struggled to identify whether the angle was valgus or varus. But, if the examiner was given the same foot consecutively they were quick to make their decision on whether the angle was valgus or varus. This may be combated by giving each examiner more specific markers as to how to identify the right from the left foot in the digital photograph. This marker could be something as simple as placing a note card on the outside of the persons right and left feet that would show in the digital photograph. By instructing the examiners that this note card marks the outside of the foot, the guesswork may be eliminated from the measurement session.

Future Research

Future research should focus on investigating the use of the DPMM on the hindfoot, when a certified athletic trainer is completing the measurements. This was not done in this study because it was assumed that the third year athletic training students would understand hindfoot valgus and varus with the education that they received during their studies in an accredited program. Future research should also investigate the effect of identifying subtalar neutral in a non-weight-bearing position, then allowing the subject to move into a weight-bearing position following the marking period. This would allow investigators to determine if there is a significant difference between subtalar neutral found in the weight-bearing position and in a non-weight-bearing position. Subtalar neutral is most easily identified in a non-weight-bearing position. If the difference is found not to be significantly different, clinicians could identify subtalar neutral in a non-weight-bearing stance and return the subject to a weight-bearing position for photographs.

Future research should be done to determine the reliability of the DPMM if each investigator were to mark and photograph each subject themselves prior to completing the measurements. To introduce this into a study each examiner would need to be taught how to find subtalar neutral in a weight-bearing position and feel comfortable doing so. Once each examiner understood how to identify subtalar neutral, they would need to take a digital photograph of the subject's foot, and complete measurements at that point. In order to assess the difference between hindfoot alignment pre- and post- injury future research must also be done using the digital photographic measure method. This would be useful to begin to understand what occurs at the subtalar joint following injuries such as strains and sprains.

Conclusion

In conclusion, this study found that there was not significant reliability between examiners when using the DPMM. However, this study did show that there is significant reliability within individual examiners when results are compared over two separate measurement sessions. This indicates that if an examiner uses the same measurement technique each session, they will have reliable and repeatable measures. This is not to say that their measures will reliably compare with other examiners measures. Future research is warranted to determine what will allow the measurement technique to be reliable across many examiners.

APPENDIX A: TABLES

TABLE 1: MEANS AND NUMBERS FOR SUBJECT CHARACTERISTICS

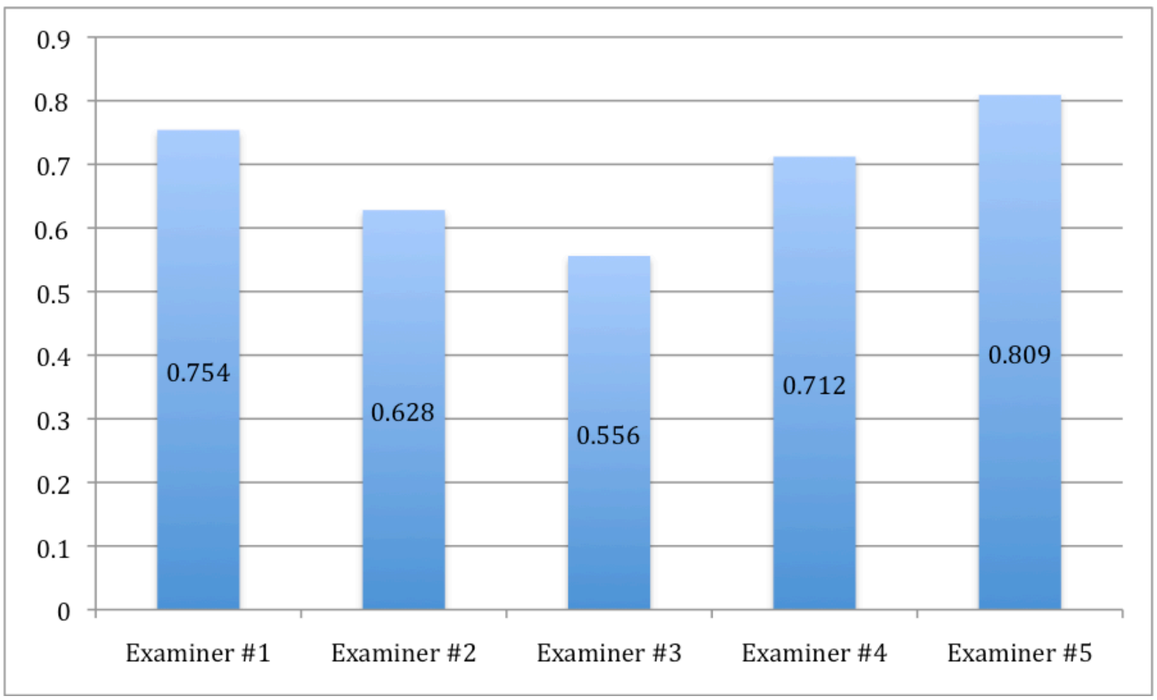
Males	4
Females	15
Average Age in Years	20.8
Participation in Physical Activity	
1 Day Per Week	3
2 Days Per Week	5
3 Days Per Week	4
4 Days Per Week	3
5 Days Per Week	3
6 Days Per Week	1
Orthotic Use	2
Prior Minor Ankle Sprain	9

TABLE 2: INTRA-CLASS COEFFICIENT (INTER-RATER RELIABILTY)

MEASUREMENT SESSION	INTRACLASS CORRELATION	95% CONFIDENCE INTERVAL
Session #1	.291	*LOWER BOUND:* .102 *UPPER BOUND:* .546
Session#2	.341	*LOWER BOUND:* .145 *UPPER BOUND:* .592

TABLE 3: EXAMINER PEARSON CORRELATIONS (INTRA-RATER RELIABILTY)

EXAMINER	PEARSON CORRELATION
Examiner #1	.754
Examiner #2	.628
Examiner #3	.556
Examiner #4	.712
Examiner #5	.809



APPENDIX B: FIGURES

FIGURE 1: DIGITAL PHOTOGRAPH WITH DIGITAL GONIOMETER

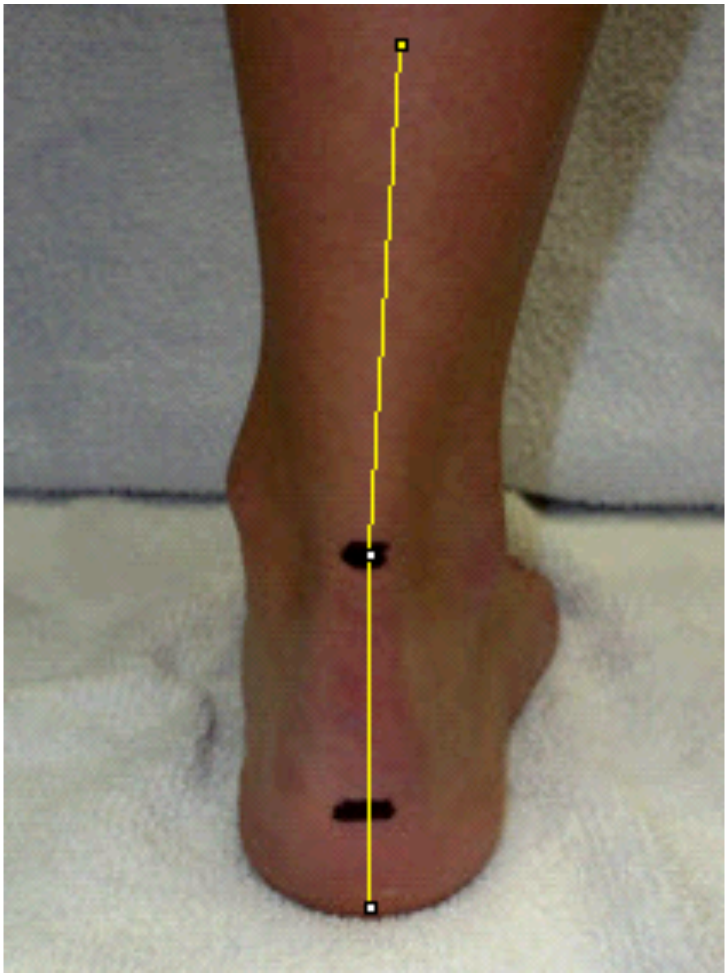


Figure 1: Photograph showing angle measure of hindfoot alignment.

FIGURE 2: PHOTOGRAPH SET UP #1

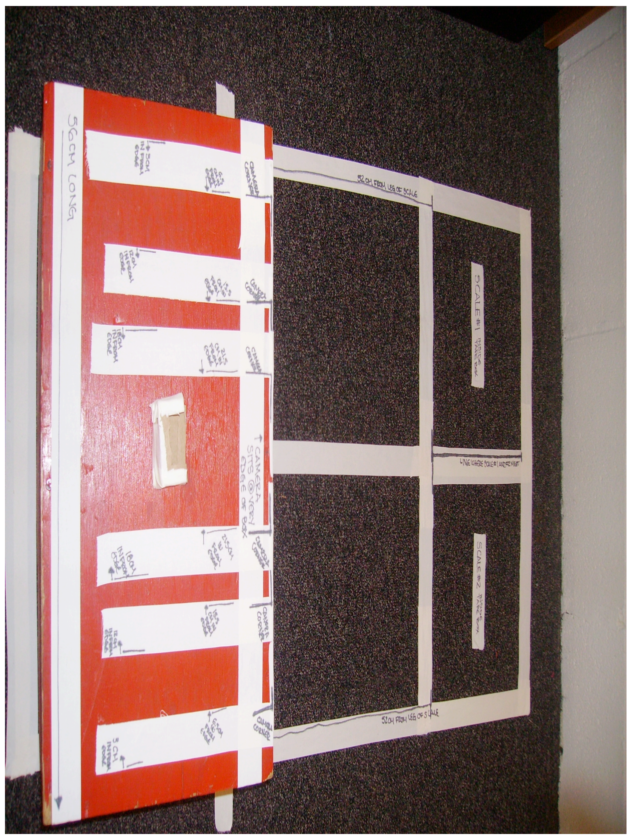


Figure 2: Photograph showing set-up for photograph session. The red box is where the digital camera sat during the session. The scales were placed directly in front of the red box in the squares pictured above.

FIGURE 3: PHOTOGRAPH SET UP #2

Figure 3: Photograph showing where the two scales which the participant stood upon sat in relation to the box the digital camera sat upon.

FIGURE 4: PHOTOGRAPH SET UP #3

Figure 4: Photograph showing box digital camera was placed on during photograph session. Each line corresponds with a line on the scale where the participant was instructed to stand for photograph.

FIGURE 5: PHOTOGRAPH EXAMPLE (LEFT)

Figure 5: Photograph showing anatomical markings and set-up on left foot.

FIGURE 6: PHOTOGRAPH EXAMPLE (RIGHT)

Figure 6: Photograph showing anatomical markings and set-up on right foot.

FIGURE 7: VALGUS/VARUS PHOTOGRAPH EXAMPLE

Figure 7: Photograph examples novice measures were given during measurement session to show what a valgus and varus angle appear as.

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